Unit 4: Further Mechanics, Fields and Particles

4.3 Further Mechanics

This topic covers impulse, conservation of momentum in two dimensions and circular motion.

It can be studied using applications that relate to, for example, a modern rail transportation system.

This unit includes many opportunities for developing experimental skills and techniques by carrying out more than just the core practical experiments.

Candidates will be assessed on their ability to:

Note that force is constant here

81	understand how to use the equation impulse $= F\Delta t = \Delta p$(Newton's second law of motion)
	Impulse (Newton's second law of motion) Impulse (Ns) = Change in Momentum (kg m/s) = Force (N) x Time (s) $I = \Delta p = mv - mu = F\Delta t$
82	**CORE PRACTICAL 9: Investigate the relationship between the force exerted on an object and its change of momentum**
83	understand how to apply conservation of linear momentum to problems in two dimensions
	Conservation of Linear Momentum in 2D - The law of conservation of linear momentum states: ***"The total momentum before a collision = the total momentum after a collision provided no external force acts*** (i.e. in an isolated system)" - Each component of momentum is conserved separately ○ Since momentum is a vector, it can be resolved into horizontal (x) and vertical (y) components ○ The **sum of horizontal components** will be equal before and after a collision ○ The **sum of vertical components** will be equal before and after a collision
84	**CORE PRACTICAL 10: Use ICT to analyse collisions between small spheres, e.g. ball bearings on a table top**
85	understand how to determine whether a collision is elastic or inelastic
	Elastic & Inelastic Collisions - Elastic collision is a *collision in which both momentum and total kinetic energy is conserved* - Commonly seen in collisions where objects move away from each other after collision - Inelastic collision is a *collision in which momentum is conserved but the total kinetic energy is not conserved* - Commonly seen in collisiosn where objects stick together after collision !Note that only KE is taken into consideration in whether a collision is elastic or inelastic, *the total energy in all forms must always be conserved*
86	be able to derive and use the equation $E_k = \frac{p^2}{2m}$ for the kinetic energy of a non-relativistic particle

$$E_k = \frac{1}{2}mv^2 \quad \text{and} \quad v = \frac{p}{m}$$

$$E_k = \frac{1}{2}mv^2$$

$$\therefore \quad E_k = \frac{1}{2}m\left(\frac{p}{m}\right)^2$$

$$\therefore \quad E_k = \frac{1}{2}\frac{p^2}{m}$$

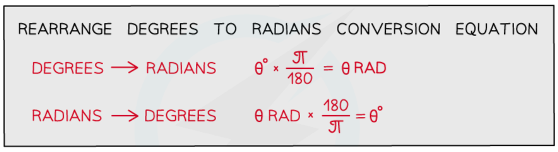
$$\therefore \quad E_k = \frac{p^2}{2m}$$

Derivation of KE
This final formula is used in calculations involving the KE of subatomic particles moving at *non-relativistic speeds* (i.e. speed much slower than speed of light)

87 be able to express angular displacement in radians and in degrees, and convert between these units

Radians and Degrees

- A **radian** is defined as:
  "The angle subtended at the centre of a circle by an arc equal in length to the radius of the circle"
- To convert from degrees to radians



Angular displacement is defined as:
"The angle in radians (degrees, revolutions) through which a point or line has been rotated in any given direction about a specified axis"

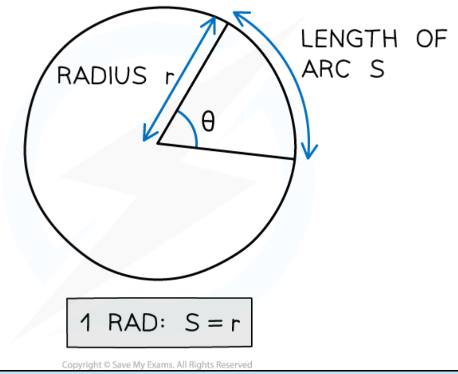
$$s = r\theta$$

linear displacement = radius x angular displacement

$$\Delta\theta = \frac{\text{distance travelled around the circle}}{\text{radius of the circle}}$$

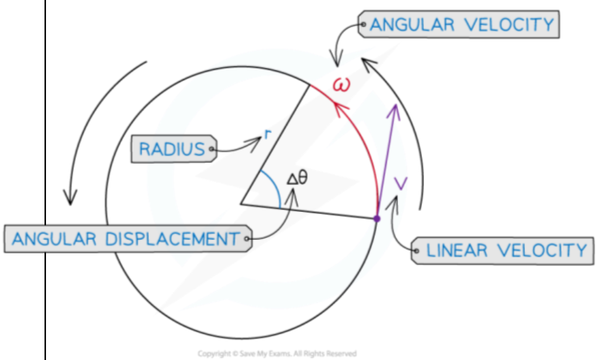
where θ must be in radians, not degrees

1 revolution = 2π rad = 360°



88 understand what is meant by *angular velocity* and be able to use the equations $v = \omega r$ and $T = \dfrac{2\pi}{\omega}$

Angular velocity is defined as:
"The rate at which angular displacement changes" (in rad/s)



$$\omega = d\theta / dt$$

If the object completes a full circle (2π radians) in a time period, T, then the angular velocity is given by:

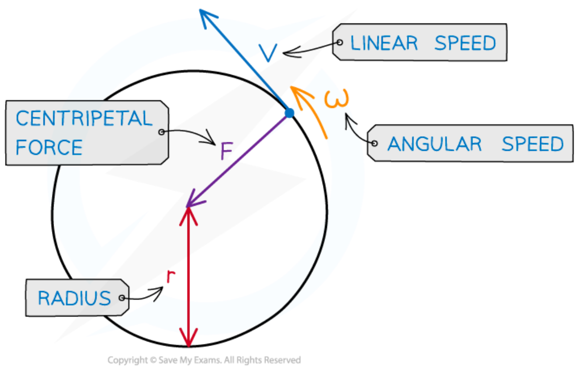
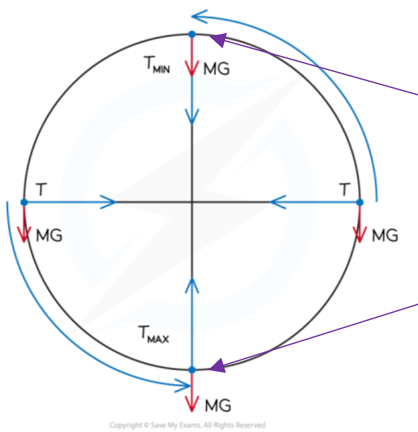
$$\omega = \frac{2\pi}{T}$$

$$\therefore \quad T = \frac{2\pi}{\omega}$$

The frequency of rotation is the reciprocal of the time period.

$$f = \frac{1}{T}$$

$$\therefore \quad \omega = 2\pi f$$

89	be able to use vector diagrams to derive the equations for centripetal acceleration $a = \frac{v^2}{r} = r\omega^2$ and understand how to use these equations
	An object moving in *uniform circular motion* travels with a *constant angular veclocity and angular speed* However, its *direction is always changing* ○ Therefore, its linear velocity changes, so it must be accelerating ○ This is called a centripetal acceleration Derivation of centripetal acceleration **Equations of Centripetal Acceleration** For any particle to move in a circular path, there must be a net force directed towards the centre of the circle to provide an acceleration, known as centripetal acceleration
90	understand that a resultant force (centripetal force) is required to produce and maintain circular motion
	Centripetal Force *F* is defined as: ***"The resultant force towards the centre of the circle required to keep a body in uniform circular motion that is always directed towards the centre of the body's rotation"*** The centripetal force is not a separate force of its own ○ It can be any type of force, depending on the situation, which keeps an object moving in a circular path ○ Eg: Magnetic force on a charged particle is always centripetal because the force acts at 90° to the charged particle's velocity
91	be able to use the equations for centripetal force $F = ma = \frac{mv^2}{r} = mr\omega^2$.
	Centripetal Force Equation $F = ma = \frac{mv^2}{r} = mr\omega^2$ The centripetal force is the **resultant** force on the object moving in a circle  **Vertical Circular Motion**  At the top of the circle, $T_{min} = mv^2/r - mg$ At the bottom of the circle, $T_{max} = mv^2/r + mg$